



Comparison of Renewable Electricity Sources for Hydrogen Production

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Hydrogen Highways Societal Benefits Public Hearing

Renewable Hydrogen Drivers

- From the Governor's Executive Order:

“...with a significant and increasing percentage [of hydrogen fuel] produced from clean, renewable sources...”
- The use of renewables for hydrogen can ensure the greatest reductions in emissions and fossil fuel dependence

How do You Produce Renewable Hydrogen?

- Renewable Electricity
 - Wind
 - Geothermal
 - Biomass
 - Solar
- Gasification
 - Biomass
- Advanced Thermal
 - Solar

Are all Renewable Electricity Options Equal?

- Renewable Electricity

- Wind
- Geothermal
- Biomass
- Solar

New Renewables vs.
Existing Renewables

Differences in types of
Renewable Purchases/
Procurement

Emissions and
Technology Comparison

California Renewable Electricity Procurement Options

- On-site generation
- Power Purchase Agreement
 - Electricity and Renewable Attributes
- “Green Tags” or Attribute Only Purchases
- Utility Green Pricing Programs

Electricity + Attributes Purchases vs. Attributes Only Purchases

- On-site, and Power Purchase Agreements do NOT result in increased grid demand in California
- Green Tags may likely result in renewable generation in a region other than California, resulting in increased grid demand here
- Impact will be an increase in marginal natural gas generation* resulting from renewable attribute only purchases

*assumed heat rate to be 8500 BTU/kWh for this study

On-Site Benefits vs. Purchased Electricity

- On-site generation eliminates transmission losses, est. $\sim 6\%$
- On-site generation eliminates scheduling losses, particularly with Wind, est. $\sim 5\%$
- On-site Solar PV hydrogen generation could eliminate DC-AC AC-DC conversions, reducing energy losses by est. $\sim 10\%$

Scaling Vectors for Rating Renewable Procurement Options

- Concept was to develop a scaling factor based on a marginal natural gas facility
 - A value of 0 = no emissions
 - A value of 1 = results in natural gas generation for the entire amount of its energy
- CO2 emissions were assumed to be reduced by an equivalent amount for purchases or green tags
- Criteria Pollutants for green tags = Criteria Pollutants for marginal natural gas generation

Renewable Procurement Scaling Matrix

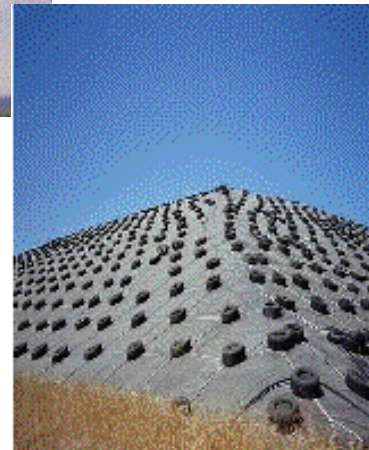
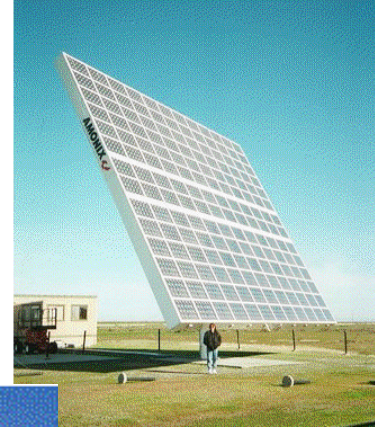
Type of Renewable Energy Procurement	Greenhouse Gas	Criteria Pollutants	Energy
Green Tags/Attribute Only Purchase	0.06	1	1
Renewable Power Purchase Agreement	0.06	0.06	0.06
On-Site Generation	0	0	0
Existing Renewable*	1	1	1

* Existing Renewable refers to a Renewable Energy Source that is already incorporated into the California electricity rate base.

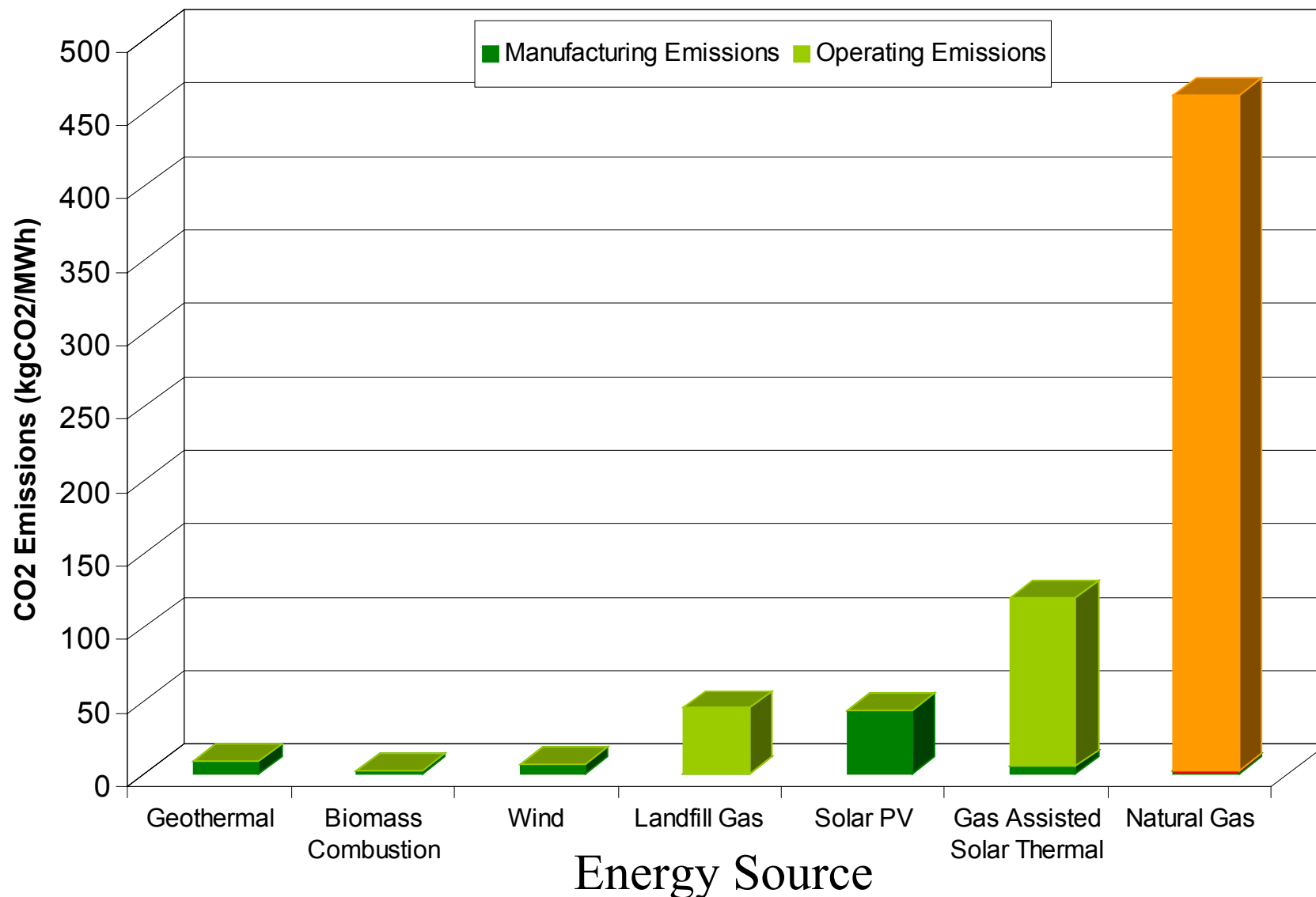
Note that the scaling factor is the fraction of the emissions of a marginal natural gas generator that will be assigned to this source in the Well to Wheels Analysis

Emissions and Technology Comparison

- Differences among renewables in the manufacturing and operating emissions
- Differences in resource availability
- Non-quantifiable considerations

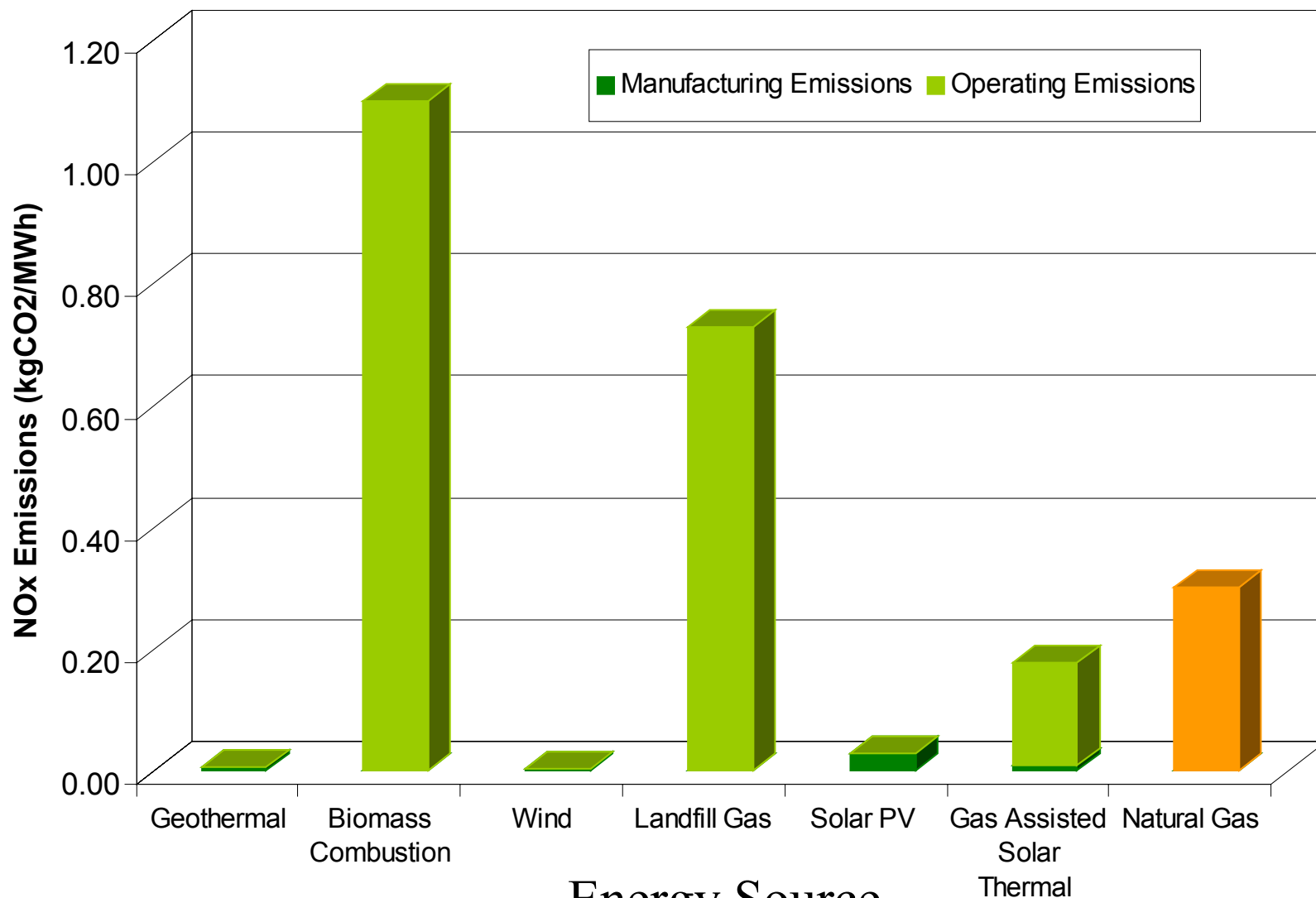


Manufacturing and Operating CO₂ Emissions for Renewable Energy Sources and Natural Gas



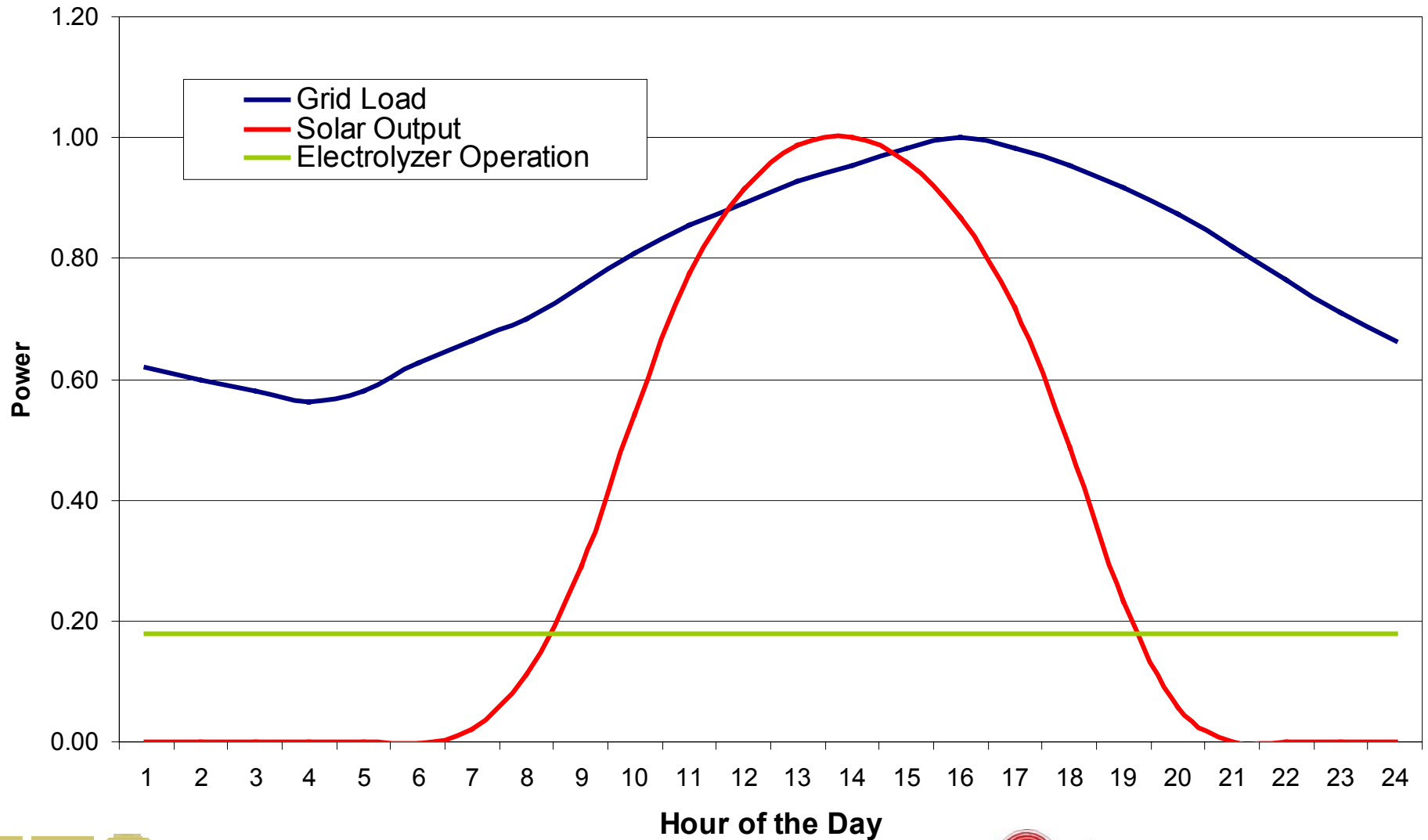
Sources: The ATLAS Project, European Network of Energy Agencies, eGRID2002 (EPA)

Manufacturing and Operating NO_x Emissions for Renewable Energy Sources and Natural Gas



Sources: The ATLAS Project, European Network of Energy Agencies, eGRID2002 (EPA)

Availability Issues



Non-Valued Characteristics

- Potential for building integration, shade provision with solar
- Loss of viewshed, and bird deaths with wind turbines
- Sustainable habitat loss/pesticide use with biomass energy crops
- “Non-renewable” nature of some renewable resources

Conclusions

- To receive full credit, renewable hydrogen must either be produced on-site or through a power purchase agreement, not green tags.
- Renewable technologies do have emissions associated with them, which are quantified for our well to wheels analysis
- Low annual availability of some renewables may affect their suitability for hydrogen production
- Non-valued characteristics could play a role in decisions about technologies, but cannot be assessed in a well to wheels analysis